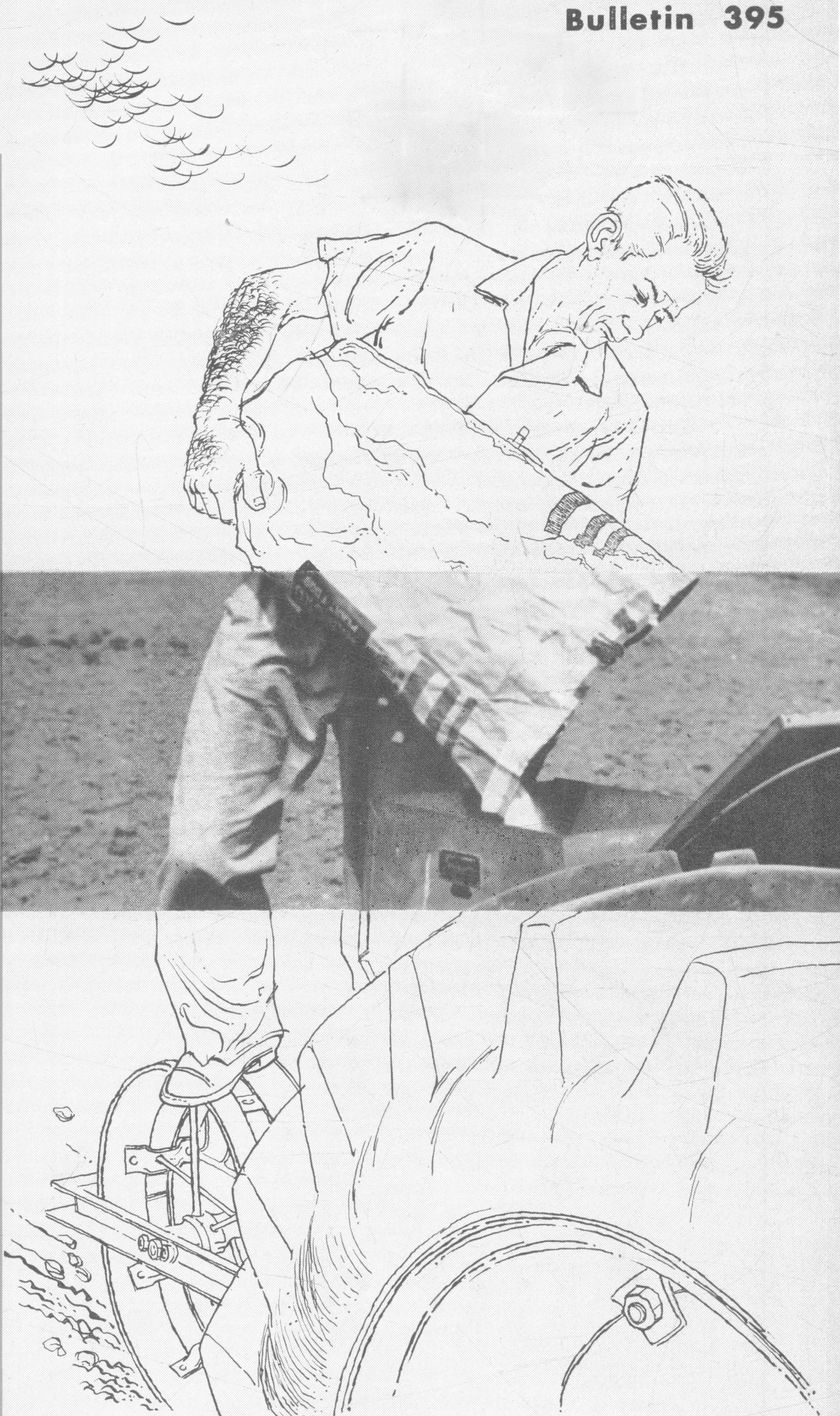
Bulletin 395

SOIL FERTILITY and FERTILIZERS
for Ohio Farms



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Soil Fertility and Fertilizers *for Ohio Farms*

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General Considerations

High crop yields and efficient production bring the highest farm income. High yielding crops require large amounts of plant nutrients, which must be supplied, in proper balance, from the soil or from commercial fertilizers.

Nutrient Removal by Crops

The approximate amounts of nitrogen, prosphorus, and potassium in selected high yielding crops are shown in Table 1. The mineral content of crops varies widely with different growing conditions. These data indicate the average plant nutrient removal by several common field crops; however, they are not the quantities of nutrients required to produce crops at the yield levels indicated.

Soil Nutrient Release

An important source of nutrients for plant growth is the continual release of soil nutrients from slowly available to more readily available forms. The speed at which these nutrients are released depends upon such factors as the total supply in the soil, the pH of the soil, the temperature, moisture and air relations, and the crops grown. The data in Table 2 show the approximate annual release of soil phosphorus (P) and potassium (K) on several experiment farms in Ohio.

Although nutrient removal by crops and the annual release of nutrients may give some indication of fertilizer needs, soil

TABLE 1
Plant Nutrients Contained in Crops*

	Nitrogen lb. N	Phosphorus lb ** P	(P_2O_5)	Potassium lb ** K	(K_2O)
Alfalfa Hay (4 tons)	190***	18	(40)	149	(180)
Corn (100 bushels)					
grain	90	17	(39)	39	(33)
stover	50	4	(9)	75	(62)
Alfalfa Timothy Hay (4 tons)	135***	15	(34)	120	(144)
Soybeans (35 bushels)					
grain	115***	14	(31)	32	(39)
haulm	20***	4	(9)	20	(24)
Red Clover Hay (2.5 tons)	94***	9	(20)	79	(95)
Wheat (40 bushels)					
grain	50	10	(24)	10	(12)
straw	23	3	(6)	30	(36)
Oats (75 bushels)					
grain	79	8	(18)	9	(11)
straw	24	5	(11)	62	(75)
Grasses (2 tons)	40	9	(20)	50	(60)

* The table lists the approximate amounts of nutrients contained in the above ground portions of farm crops and indicates the plant nutrients removed by crops. These are not the quantities of nutrients required to produce crops at the yield levels indicated.

** P and K indicate elemental phosphorus and potassium, respectively. P_2O_5 and K_2O are phosphate and potash such as are used in commercial fertilizers.

*** Inoculated legumes fix nitrogen from the air. Growing legume meadow results in a build up rather than a depletion of soil nitrogen. Soybeans fix approximately the quantity of nitrogen contained in the crop, and thus frequently do not appreciably alter the nitrogen status of soils.

TABLE 2
Annual Release of Phosphorus and Potassium
(Rotation—Corn, Oats, Wheat, Hay—1934–1946)

Location of Experiment Farm (county)	Nutrients Released—Pounds Per Acre Per Year Phosphorus P	(P_2O_5)	Potassium K	(K_2O)
Belmont	6	(14)	43	(52)
Clermont	4	(9)	32	(39)
Hamilton	8	(18)	54	(65)
Madison	6	(14)	48	(58)
Mahoning	6	(14)	45	(54)
Meigs	3	(7)	30	(36)
Miami	8	(18)	59	(71)
Paulding	13	(29)	91	(110)
Trumbull	7	(16)	61	(74)
Washington	6	(14)	50	(60)
Wayne	9	(20)	58	(70)

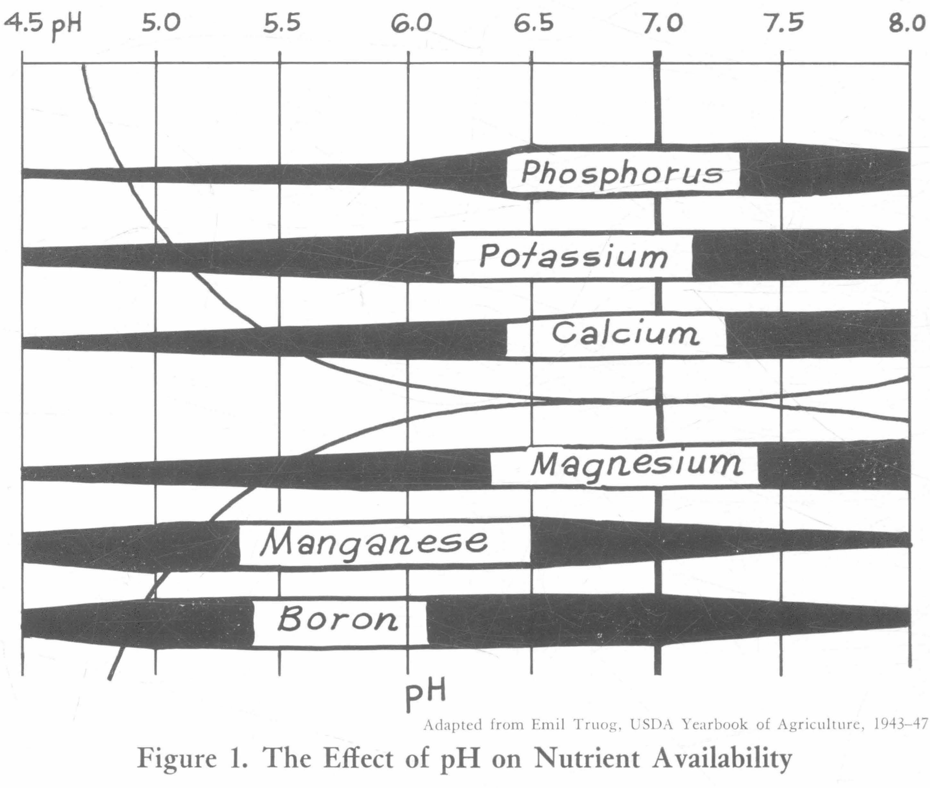
(Adapted from data published in "Handbook of Ohio Experiments in Agronomy 1957") tests measure the quantity of "available" nutrients in the soil and are the best guide to profitable use of commercial fertilizers.

A summary of several thousand recent Ohio soil tests is given in Figure 2, pages 16 and 17. This summary shows that the levels of phosphorus and potassium vary greatly among the major soil areas. These results point to the need for different fertility practices in the various soil areas.

Soil pH and Fertitity

The relative availability of several elements at different pH values is shown in Figure 1. In this chart, nutrient availability is indicated by the width of the bar. Note, for example, that phosphorus availability increases gradually as the pH is increased from 4.5 to 6.0 and increases rapidly from pH 6.0 to 6.5. The availability

Collecting a soil sample.



Adapted from Emil Truog, USDA Yearbook of Agriculture, 1943–47

Figure 1. The Effect of pH on Nutrient Availability

of phosphorus is shown to decline when the pH exceeds 7.5.

Soil fertility is only one of the factors which limit crop yields. The availability of nutrients to plants is affected by soil tilth, degree of acidity or alkalinity, organic matter, drainage and moisture. High yields are possible only where adequate fertility and good soil management are accompanied by recommended crop production practices such as the use of adapted varieties or hybrids, planting at proper date and rates, adequate weed control and timely harvesting.

Other good management practices, including erosion control and the use of adapted crop rotations, are also essential to high crop yields. Where crop production is limited by factors such as poor tilth, poor drainage, excess soil acidity, or lack of moisture, yield response to fertilizers will be less than under optimum conditions.

Fertilizer Materials and Plant Nutrients

Nitrogen (N)

Nitrogen is an inert gas which makes up about four-fifths of the earth's atmosphere. Plants cannot use this vast quantity of nitrogen directly from the air; it must first be combined with hydrogen or oxygen. Certain bacteria have the ability to "fix" atmospheric nitrogen in nodules on legume roots; this nitrogen then becomes available to plants.

Small amounts of available nitrogen are brought to the soil in snow and rain. Although some fertilizers contain nitrogen from organic sources (animal and plant wastes or residues), most commercial fertilizer nitrogen is obtained from the air by one of several manufacturing processes.

Nitrogen is needed in large amounts by all growing crops. It promotes leaf and stem growth and helps to increase crop yields. It increases the protein content of food and feed crops and causes dark, healthy green color in plant leaves.

Too much nitrogen may cause lodging of small grain crops, particularly when the available soil phosphorus and/or potassium is low. Excess nitrogen reduces the quality of tobacco and certain fruits.

Nitrogen-deficient plants have pale, yellow-green leaves, grow slowly, and yield poorly.

Organic Matter

Organic matter has been called the "life of the soil." It affects the physical and chemical condition of the soil and is a major source of food for soil micro-organisms. The organic matter content of mineral soils varies from less than 1 percent to 20 percent; organic soils may contain as much as 90 percent organic matter.

Organic matter is the storehouse of soil nitrogen. Nearly all of the soil nitrogen is in the organic matter. This nitrogen is released as ammonium or nitrate nitrogen as the organic matter breaks down or decomposes. Even in very fertile soils, ammonium and nitrate nitrogen are seldom present in large amounts. The nitrogen fertility of soils is primarily dependent upon the ability of the soil to release nitrogen throughout the growing season.

In addition to serving as a storehouse and source of ntrogen, organic matter improves the physical condition of soils, increases air and water-holding capacity, and provides a supply of other essential plant nutrients.

A build-up of soil organic matter, although often desirable, is not accomplished easily or quickly. About 10 tons of raw plant material (dry basis) are required to produce one ton of organic matter. To increase the organic matter content of the plow layer of a mineral soil by 1 percent would require adding 10 tons of organic matter which would be produced from 100 tons of plant material (dry basis) such as green manures or crop residue.

In spite of the large amounts of materials required, it is possible to maintain or gradually increase the organic matter content of most mineral soils. The best ways are to produce sod crops, store and use of animal manures carefully, use adequate quantities of nitrogen fertilizers, and return to the soil the residue from high-yielding crops.

On most farms, high-yielding crops provide the most readily available and economical source of organic matter. These develop extensive root systems and produce large amounts of top growth, much of which is returned to the soil where it decomposes to form organic matter.

The annual turnover—breakdown and replenishment — of organic matter is of much greater importance in securing satisfactory crop yields than is the total organic matter content of soils.

Nitrogen Fertilizers

There are four general classes of nitrogen fertilizers: (1) nitrate salts, (2) ammonium salts, (3) natural organics, and (4) synthetic organics. Growing plants take up nitrogen in either the ammonium (NH_4) or nitrate (NO_3) forms.

Nitrate nitrogen applied to the soil goes into solution and moves with soil moisture. If rains are heavy and the movement of the soil water is down and out as drainage water, some of the nitrate nitrogen goes with it. If the season is dry and water moves up in the soil, nitrates move up and are deposited near the soil surface. These nitrates are again available to the plant when there is sufficient rainfall to carry them back into the root zone. Nitrate nitrogen should therefore be applied only during or immediately prior to the growing season.

Ammonium nitrogen applied to the soil goes into solution and is rapidly adsorbed by the soil until it is taken up by growing plants or is changed to nitrate nitrogen by soil bacteria. In the nitrate form it is subject to movement with soil water. This change to nitrate nitrogen occurs most rapidly when the soil is warm, moist and well aerated.

Ammonium nitrogen can be applied during the fall or early spring when the soil temperatures are below 50-55°F. with little loss from leaching. At these temperatures, soil bacterial activity is greatly reduced, and there is very little conversion from ammonium to nitrate nitrogen.

Organic nitrogen (natural or synthetic) is changed to the ammonium and/or nitrate forms in the soil. The formation of ammonium nitrogen from urea and cyanamid occurs within a few days after application. Until converted to ammonium nitrogen, cyanamid may be toxic to plants and therefore it should not be applied close to germinating seeds or plant roots. However, cyanamid has been used successfully as an early spring top dressing on wheat.

Urea-form fertilizer materials, made by combining urea and formaldehyde, are low in solubility and when applied to the soil break down slowly releasing available nitrogen over a long period of time. Because of their low solubility urea-forms do not burn vegetation or interfere with germination.

Composition and Properties of Nitrogen Fertilizer Materials

The composition and some of the properties of several common nitrogen fertilizer materials are shown in Table 3.

The *salting out temperature* is the temperature at which crystals begin to form in solution of these materials. Solutions should be applied at temperatures higher than the salting out temperature.

Nitrogen fertilizers vary in their effect on soil acidity. The residual effect on soil reaction, in terms of $CaCO_3$ (limestone) per 20 pounds of nitrogen applied, is given as minus (—) indicating acid and plus (+) indicating basic reaction in the soil.

Nitrogen in most complete fertilizers is principally in the ammonium form.

General Considerations in Choosing Nitrogen Fertilizer Materials

1) Growing plants can take up either ammonium or nitrate nitrogen; however, when the soil moisture, aeration and temperature are satisfactory for good plant growth, ammonium nitrogen is quickly converted to nitrate nitrogen and the plants actually get most of their nitrogen in the nitrate form.

2) Nitrogen in the ammomium form applied during the fall, winter or early spring is not likely to change to nitrate form and leach as long as soil temperatures of 50-55° or lower. Thus for fall, winter or early spring applications, the use of ammonium, urea, cyanamid or urea-form nitrogen fertilizers is recommended. This recommendation applies only to fine textured soils. On coarse textured soils (sandy) supplemental nitrogen should be applied just prior to or during the growing season.

3).For plow-down just prior to planting, topdressing small grains and sod crops, or for sidedressing, the ammonia, nitrate and urea forms are satisfactory.

4) Anhydrous ammonia is subject to loss unless it is applied 4 to 6 inches below the soil surface and is well covered. Solutions containing less volatile ammonia remain in the soil when applied 2 to 4 inches below the soil surface.

TABLE 3
Composition and Properties of Some Nitrogen Fertilizer Materials

Material	Total Nitrogen Percent	Ammonium Nitrogen Percent	Nitrate Nitrogen Percent	Volatile Ammonia Nitrogen Percent	Salting Out Temperature Degrees F.	Pounds $CaCO_3$ Equivalent Per 20 lb. N
Ammonium Sulfate	20.6	20.6	...	...	...	−107
Cyanamid	21.0	21.0	...	...	...	+57
Urea Compounds	45.0	45.0	...	...	...	−36
Ammonium Nitrate	33.5	16.7	16.7	...	...	−36
Nitrate of Soda	16.0	...	16.0	...	...	+36
Urea Formaldehyde*	38.0	38.0	...	...	...	−36
Anhydrous Ammonia	82.2	82.2	...	82.2	...	−36
Nitrogen Solution Low Pressure	41.0	11.4	11.4	18.26	21.0	−36
Nitrogen Solution No Pressure	32.0	24.25	7.75	...	32.0	−36

* Nitrogen is released slowly. This material is used mainly in specialty fertilizers, such as lawn or turf fertilizers.

(Adapted from mineograph: "Nitrogen Fertilizers—Sources and Uses" by Reed and Volk.)

Phosphorus

Phosphate rock, in which the phosphorus is combined with calcium and flourine, occurs in large quantities in a number of locations in the world. The Florida deposits are the principal source of the phosphate rock currently mined in the United States. Other deposits are found in Tennessee, Idaho, Wyoming, and South Carolina.

A plentiful supply of available phosphorus in the soil promotes rapid growth, hastens maturity, and stimulates flower, seed, and fruit production. It is especially important in promoting rapid growth of young seedlings.

Under some conditions, plants deficient in phosphorus develop a reddish-purple color; however, under other conditions, phosphorus deficient plants may have normal color but make little growth.

Phosphorus in the Soil

The phosphorus problem in soils is twofold: (1) the amount of phosphorus in soils is generally low, and (2) most phosphate compounds are only slightly soluble in soils.

The total phosphorus content of soils may range from less than 100 to several thousand pounds per acre in the plow layer. The subsoil also contains some phosphorus. Most of the total soil phosphorus supply is tied up chemically in a form that is not usable by the crop in a single growing season. The available soil phosphorus comes from the breakdown of soil minerals, from organic matter, or from the previous addition of phosphate fertilizer.

The available soil phosphorus is not necessarily related to the total soil phosphorus. The differences in available phosphorus in agricultural soils are due primarily to management practices, which affect the available phosphorus much more than they affect the total phosphorus. While high fertilization increases available soil phosphorus more than total soil phosphorus, crop removal without fertilization rapidly lowers the available phosphorus without appreciably changing the total phosphorus.

Soil phosphorus may be divided into two general classes, *organic* and *inorganic*. The organic forms are present in the organic matter which is found mainly in the surface soil. Organic phosphate may comprise 35 percent or more of the total phosphorus in the soil, but soils with little organic matter generally contain much smaller amounts.

The inorganic forms of phosphorus in the soil are complex. The primary source of phosphorus in most soils is the mineral, apatite, which is tri-calcium phosphate in combination with calcium fluoride. Tri-calcium phosphate breaks down slowly through the action of soil acids and bacteria to form di-calcium and mono-calcium phosphates, both of which are available for crop use. This breakdown process generally is too slow to supply the entire needs for high crop yields.

Since many of Ohio's soils are quite acid, much of the phosphorus is present as iron and aluminum phosphates which are not readily available sources of phosphorus for plants. In strongly acid soil, the phosphorus from added phosphate fertilizers will be changed to one of these relatively insoluble forms. It has been found that soil phosphorus has its greatest availability when the pH is between 6.5 and 7.0. One of the benefits of liming acid soils is to provide a range of acidity in which phosphorus is more available.

The process of changing soluble phosphate into less soluble phosphates in soils is called *fixation*, or *reversion*. When phosphate fertilizer is added to the soil, the soluble phosphorus compounds in it react with the soil and are changed into less soluble and less available form. Actually, only a relatively small proportion (generally less than 20 to 25 percent) of the phosphorus applied in phosphate fertilizers is recovered by the plants during the growing season of the application. Even though the recovery of applied phosphorus is small, it may greatly increase crop yields.

Studies of growth and total phosphorus uptake have shown that 50 percent of the total plant phosphorus may have been absorbed when only 20 percent of the total growth has occurred. The smaller root system and competition for available phosphorus by micro-organism emphasize the need for large supplies of available phosphorus in the early stages of growth. These factors favor annual application of soluble phosphorus fertilizers at planting time for most common field crops.

Phosphorus Fertilizers

Terms used to denote the types of phosphorus in fertilizers are: (1) available, (2) water soluble, (3) citrate soluble, (4) citrate insoluble, and (5) total. Phosphorus which readily dissolves in one normal ammonium citrate is designated as "available" or "citrate soluble" phosphorus. That portion of the citrate soluble phosphorus which dissolves in water is called "water soluble." Total phosphorus includes both the available (citrate soluble) and the citrate insoluble phosphorus.

The phosphorus content of fertilizers is expressed as the percentage of available (citrate soluble) phosphorus in terms of P_2O_5 (phosphorus pentoxide). Some incorrect and/or loosely defined terms are frequently used in connection with fertilizer phosphorus. P_2O_5 is sometimes incorrectly called "phosphorus" or phosphoric acid," and at other times is referred to as "phosphate." The fact that the phosphorus in fertilizers is combined with calcium, ammonium, hydrogen and other elements but never occurs as P_2O_5 adds further to the confusion.

A recommendation that the phosphorus content of fertilizer be expressed as the element (P) rather than the oxide (P_2O_5) is being considered in several midwest states. At least one company is now listing phosphorus in terms of P_2O_5 and also as P on its fertilizer analysis. To convert pounds of P to P_2O_5, multiply the pounds of P by a factor of 2.3. To convert pounds of P_2O_5 to P, multiply pounds of P_2O_5 by 0.435.

Water Solubility of Phosphorus Fertilizers: Since most nutrients enter plants from the soil solution, it would appear that phosphorus materials which are soluble in water should be more readily available to plants than those forms of phosphorus which are not water soluble. The difficulty with this reasoning is that water soluble forms of phosphorus are quickly changed to water insoluble forms in the soil. On acid soils, water soluble phosphates are changed to the very slowly available iron and aluminum phosphates. On neutral or alkaline soils the water soluble phosphates are changed to the moderately soluble calcium phosphates. Thus a phosphate fertilizer which is highly water soluble may be the most rapidly converted to a less soluble form in the soil.

With short-season, quick-growing crops which are grown during the early spring season, such as some horticultural crops, there is an advantage in the use of highly water-soluble phosphates. About one-half of the available (citrate soluble) phosphorus in the starter fertilizer for corn and small grains should be water soluble. In most complete mixed fertilizers available in Ohio, one-half or more of the available phosphorus is water soluble. The analysis of some typical phosphorus fertilizers is shown in Table 4.

TABLE 4
Analysis of Typical Phosphorus Fertilizers

Fertilizer	Percent P_2O_5		Percent Available P_2O_5 which is water soluble
	Total	Available	
20% Superphosphate	21	20	85
Concentrated superphosphate	47	45	85
Calcium metaphosphate	64	63	1
Ammonium phosphate (11–48–0)	49	48	92
Rock phosphate	34	3–8	0
Complete mixed fertilizer, i.e., (5–20–20)'	21 (approx.)	20	50

Superphosphates: The most commonly used phosphate fertilizer is superphosphate. Two commercial forms are produced: (1) ordinary superphosphate, containing 16 to 20 percent available P_2O_5, and (2) concentrated superphosphate, containing 45 to 50 percent available P_2O_5.

Ordinary superphosphates (0-20-0) are usually made by mixing rock phosphate with about an equal weight of sulfuric acid. Most of the phosphorus in the rock is changed to mono-calcium phosphate, of which about 85 percent is water soluble. Gypsum (calicum sulfate) is also formed when ordinary superphosphate is manufactured and makes up about half of the weight of this fertilizer. Currently, about 85 percent of the P_2O_5 used as fertilizer in the United States is ordinary superphosphate.

Higher analysis superphosphate fertilizers contain 45 to 50 percent available phosphoric acid (P_2O_5) of which about 85 percent is water soluble. They are usually called concentrated, double or triple superphosphate; as in ordinary superphosphate, mono-calcium phosphate is the main phosphorus compound. The concentrated superphosphates (0-45-0 to 0-50-0) are made by treating phosphate rock with phosphoric acid. Since no gypsum is formed in this reaction, these fertilizers are higher in phosphorus than ordinary superphosphate.

Experiments in Ohio and other midwest states indicate that ordinary and concentrated superphosphates are equally effective when equal amounts of available phosphorus are applied.

A ton of 0-45-0 will supply the same amount of available P_2O_5 as 2¼ tons of 0-20-0. Due to savings in freight, bags, and handling the ton of 0-45-0 usually can be purchased for less than 2¼ tons of 0-20-0.

Calcium Metaphosphate: (0-60-0 to 0-63-0) made by the Tennessee Valley Authority is now available in limited quantities. It is made by treating rock phosphate with phosphoric oxide made from burning phosphorus obtained in the smelting of phosphate rock. It contains 60 to 63 percent available P_2O_5, most of which is citrate-soluble and very little (less than 1 percent) is water soluble. Because of its low water solubility, it is not effective for use as a starter fertilizer for corn or small grains. The primary use of this material is for topdressing meadows and pastures or building a phosphorus reserve in the soil.

Ammonium Phosphates: (11-48-0, 21-53-0) fertilizer grade ammonium phosphate is produced by treating phosphoric acid with ammonia and evaporating the solution. The material consists of a mixture of mono-ammonium and diammonium phosphates. The phosphorus in ammonium phosphates is largely water soluble.

Rock Phosphate: Naturally occurring phosphate rock (raw rock phosphate) containing 30 to 36 percent total P_2O_5 is mined, finely ground, and sold as a phosphate fertilizer. Only a small percentage of the total phosphorus contained in raw rock phosphate is readily available to plants. The low availability is due to a chemical tie up of the phosphorus with calcium and fluorine. Treating with acids as in the manufacture of superphosphates releases the phosphorus from the fluorine.

Crops differ in their ability to use the phosphorus in rock phosphate. Corn, small grains, and grasses respond poorly to rock phosphate. Legumes, particularly alfalfa, sweet clover and red clover, give the best response to rock phosphate but even with these legumes super or treated phosphates are more effective in increasing yields and are generally more economical.

Rock phosphate should never be used directly under any short-season row crop with the idea that phosphorus will be supplied to that crop. Its availability is low, and its use should be considered only when large amounts (1,000 to 2,000 pounds per acre) are applied to long-lay meadows or to rotations including several years of alfalfa.

Fifty years of research in Ohio and neighboring states have shown superphosphate to be generally superior to rock phosphate as an economical source of phosphorus for farm crops. Rock phosphate is most nearly equal to superphosphate when the two materials are applied to acid, low producing soils which give only a small response to phosphorus from any source.

Miscellaneous Phosphorus Fertilizers: *Collodial phosphate* is a finely divided, relatively low grade type of rock phosphate. It is obtained from the settling ponds used in the mining of phosphate rock. Collodial phosphates contain 18 to 24 percent total P_2O_5 which has approximately the same availability as the phosphorus in raw rock phosphate.

Basic Slag is a by-product of the steel manufacturing industry. A mixture of limestone and iron ore are heated in a furnace. The impurities in the iron ore combine with the limestone and are removed with it. When the iron ore is high in phosphorus, as it is from some ore fields in the southern part of the United States, this blast furnace slag (limestone and impurities removed from the iron ore) may contain 8 to 10 percent total P_2O_5 of which 60 to 90 percent is citrate soluble.

Bone Meal contains 20 to 28 percent total P_2O_5 of which about 50 percent is citrate soluble. Much of the current production of bone meal is used by the feed industry; however, some still finds its way into fertilizers, particularly specialty mixed fertilizers. It is a good source of phosphorus for plants, but it is expensive.

Liquid Phosphoric Acid is becoming more important as interest in liquid fertilizer increases. The combination of this acid and anhydrous ammonia to form nitrogen-phosphate mixture is common. In some cases potassium salts are added to form a complete mixed liquid fertilizer.

Potassium (K)

Most soils contain relatively large amounts of potassium; however, only a small fraction of this potassium becomes available to plants during any one cropping season.

The potassium content of fertilizers is expressed as K_2O (potassium oxide). As with phosphorus, incorrect or loosely defined terms are often encountered. In common usage, the term "potash" usually means potassium oxide (K_2O); however, at times K_2O is incorrectly referred to as "potassium." In fact, there is no K_2O, as such, in fertilizers and a recommendation that the potassium content of commercial fertilizers be expressed as K is being considered by several states. One manufacturer currently lists the potassium content of fertilizers in terms of K_2O and also in terms of K. To convert from pounds of K to pounds of K_2O, multiply the pounds of K by 1.2. To convert pounds of K_2O to K, multiply the pounds of K_2O by 0.83.

Although potassium is widely distributed and most soils contain relatively large quantities of it, potassium salts which can be mined and used in fertilizers occur in only a few places in the United States. The most important deposits are located in New Mexico, Utah, California, Texas, and other western states. Recent developments in Canada promise to make this an area of great importance in potash production.

Potassium deficient plants produce small, light green or yellow colored leaves and make only limited growth. Potassium has a marked effect on the growth of plant roots; and crops grown on potassium deficient soils are more susceptible to root lodging and stalk breakage than are plants well supplied with potassium.

Potassium in the Soil

Soil potassium exists in three forms: (1) relatively unavailable, (2) slowly available, and (3) readily available. In the soil these three forms of potassium are in equilibrium with one another and a change in the supply of any form results in changes in the others.

Because of the continual removal of potassium from the soil by leaching and uptake by crops, an equilibrium condition in the strict sense of the word probably never exists. There is a continuous but very slow transfer of potassium in the primary minerals to exchangeable and slowly available forms. Under some soil conditions, high applications of potassium may cause some reversion to slowly available forms. According to current estimates of the total potassium in soils, the unavailable form accounts for 90 to 98 percent, the slowly available form accounts for 1 to 10 percent, while the readily available form accounts for 1 to 2 percent.

Knowledge that the surface and subsoil contain large total quantities of potassium and that this element may gradually be changed to the available form suggests that greater use of this potential supply should be made. This can be done to a certain extent by growing crops, such as alfalfa and corn, known to be effective users of soil potassium, and by liming the soil to help prevent loss by leaching of the potassium that is released. It should not be inferred that soil potassium alone will supply all of the crop requirements on all soils. It should be remembered, however, that crops growing on soils high in potassium and in good physical condition may be able to use effectively some of this supply, thereby reducing the amount to be supplied in the fertilizer.

While most soils contain large quantities of total potassium, the release of the unavailable portion to those forms available to plants is usually too slow to supply the potassium needs of high yielding crops. Approximate annual potassium release rates are given in Table 2.

The phenomenon of luxury consumption by plants as well as possible loss of potassium in leaching waters suggests that potassium fertilizers under some conditions should be applied more frequently and in smaller quantities. However, on many soils (fine textured), the bulk of the potassium for the rotation may be applied once every 2 to 4 years.

Potassium Fertilizer Materials

The potassium salts contained in fertilizers are water soluble and readily available to plants.

Potassium Chloride: This is sold under the name of muriate of potash. Over 90 percent of the fertilizer potassium consumed in the United States is furnished by muriate of potash (potassium chloride).

Potassium Sulfate: Potassium sulfate is used when the chlorine in muriate of potash may be detrimental, such as tobacco fertilizers.

Secondary and Trace (Minor) Elements

Secondary Elements

Calcium, magnesium, and sulfur are often termed as secondary elements. It should be emphasized, however, that these elements are as necessary for plant growth as are the primary elements (nitrogen, phosphorus, and potassium).

Most Ohio soils contain enough *calcium* and *magnesium* to supply the needs of farm crops. In addition, large amounts of calcium and magnesium may be supplied when agricultural liming materials are applied to the soil. Dolomitic limestone should always be used for liming soils that contain only moderate amounts of native magnesium. When a shortage of magnesium occurs on soils which do not require lime (soils with pH values of 6.5 or higher) the deficiency may be corrected by an application of 300 pounds per acre of magnesium sulfate.

Sulfur is rarely, if ever, lacking in the mineral soils of Ohio. Many fertilizers contain sulfur, and large quantities of sulfur are deposited annually on Ohio soils from the smoke and fumes of industrial plants. However, high-analysis fertilizers often contain much less sulfur than is contained in lower analysis materials, and in some areas coal is being replaced by other fuels.

If these trends continue, it is possible that Ohio soils may at some future date become deficient in sulfur. If this occurs, calcium sulfate would be recommended to correct sulfur deficiencies.

Trace (Minor) Elements

The trace elements, manganese, copper, zinc, boron, iron, and molybdenum are required by plants in only extremely small amounts. With the exception of manganese and boron, most Ohio soils contain enough of these elements to supply crop needs.

Manganese deficiencies are most prevalent on the lake-bed soils of northwestern Ohio. The deficiencies are spotty on the sandy soils and are more widespread on the fine textured soils of this area.

The lack of manganese is most frequently noticed in soybeans; however, deficiencies may occur in other crops, including oats, wheat, and alfalfa.

The common manganese deficiency symptoms in soybeans are light green to yellow leaves with distinctly green veins. In severe cases, brown spots appear on the leaves and the leaves drop prematurely.

TABLE 5

Potassium Containing Fertilizer Materials

Fertilizer Material	Form of Potassium	Percentage of K_2O
Potassium Chloride (Muriate)	K Cl	60
Potassium Sulfate	K_2SO_4	50
Sulfate of potash—magnesia	K_2SO_4–$MgSO_4$	22
Manure salts	K Cl, NaCl	25
Potassium nitrate	KNO_3	44
Potassium metaphosphate	KPO_3	35
Tobacco stems	Organic	7

Manganese deficiencies may be prevented by applying manganese sulfate at a rate of 14 pounds per acre. The manganese sulfate should be mixed with other fertilizers; however, fertilizers containing it may cake and set up quickly and should be applied soon after they are purchased.

Manganese deficiencies may also be corrected by spraying the foliage with manganese sulfate. The recommended application is 5 to 10 pounds of spray-grade manganese sulfate per acre in 10 to 20 gallons of water. The spray should be applied as soon as leaf discolorations appear.

Boron deficiencies have been found in a few fields widely scattered throughout Ohio. Many instances of reported boron deficiencies in alfalfa have, under more careful study, proven to be insect injury. Where true boron deficiencies exist, field crops including corn, soybeans, small grains, and meadow crops are affected.

Boron deficiencies may be corrected by an application of 25 to 30 pounds per acre of borax (sodium tetraborate containing 10.5 to 13.5 percent boron). The borax should be mixed with fertilizers and applied as a topdressing on meadows, or broadcast and disked into the soil prior to the planting of grain crops.

Row applications close to germinating seed or young seedlings frequently kill or severely damage the plants. *Fertilizers containing boron should not be applied as a starter fertilizer in the row for corn, sorghum, or soybeans or with small grains at seeding.*

Figure 2

SUMMARY of PHOSPHORUS and POTASSIUM

MAJOR SOIL TYPES by SOIL AREAS

1

Hoytville, Nappanee, Toledo, Paulding & associated soils

2

Morley, Blount, Pewamo & associated soils

3

Miami, Celina, Crosby, Brookston & associated soils

4

Russell, Xenia, Fincastle & associated soils

5

Clermont, Avonburg, Blanchester, Rossmoyne, Cincinnati & associated soils

6

Alexandria, Cardington, Bennington, Marengo & associated soils

7

Rittman, Wadworth, Trumbull, Mahoning, Cambridge, Venango & associated soils

8

Wooster, Canfield, Massillon, Ravenna & associated soils

9

Muskingum, Wellston, Meigs, Westmoreland, Upshur & associated soils

…UM STATUS by MAJOR SOIL AREAS

PERCENT of SAMPLES TESTING

Phosphorus

	Low	Medium	High
1	54	18	28
2	59	19	22
3	68	15	17
4	59	16	25
5	60	10	30
6	58	16	26
7	52	18	30
8	44	21	35
9	68	12	20

Potassium

	Low	Medium	High
1	6	11	83
2	2	23	75
3	5	33	62
4	14	41	45
5	30	30	40
6	10	33	57
7	12	39	49
8	7	37	56
9	8	29	63

Mixed Fertilizers

Mixed fertilizers are those containing two or more of the primary (nitrogen, phosphorus, potassium) elements. Such fertilizers are made by various chemical combinations of the fertilizer elements or by mixing two or more materials containing single fertilizer elements.

The terms "fertilizer grade" and "fertilizer ratio" are used in connection with mixed fertilizers. Grade refers to the analysis listed on the fertilizer bag, or on the sales ticket which comes with liquid fertilizers.

Ratio refers to the relative amounts of the various nutrients in the fertilizer. In Figure 3, the 4–16–16 grade indicates that the material contains 4 percent nitrogen, (N), 16 percent available phosphate (P_2O_5), and 16 percent available potash (K_2O).

For each part of nitrogen there are four parts each of phosphate and potash. Thus the ratio is 1:4:4. The ratio of any fertilizer is determined by dividing each of the numbers of the fertilizer grade by the smallest of these numbers. There may be many grades of the same ratio. For example, 3-12-12, 4-16-16, 5-20-20, and 6-24-24, all have the same 1:4:4 ratio. This is significant in that once the ratio of nutrients needed is known there is a choice in the grade that may be used.

Table 6 lists equivalent amounts of several fertilizer grades of the commonly used fertilizer ratios.

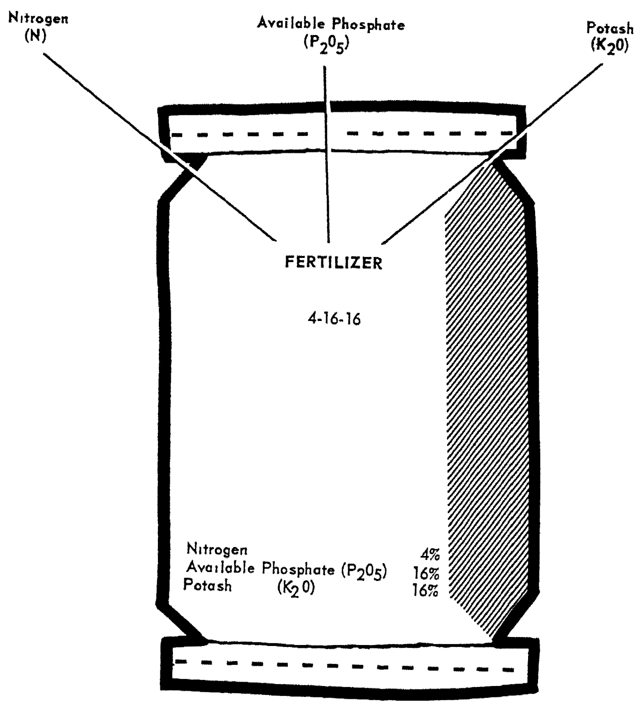


Figure 3. What's in the "Fertilizer Bag"

TABLE 6
Equivalent Amounts of Various Fertilizers

Ratio	Equivalent Amounts (pounds)			
1:4:4	3–12–12	4–16–16	5–20–20	6–24–24
	200	150	120	100
	400	300	240	200
	600	450	360	300
1:4:2	4–16–8	5–20–10	6–24–12	
	200	160	133	
	400	320	266	
	600	480	400	
1:2:2	5–10–10	6–12–12	8–16–16	10–20–20
	200	166	125	100
	400	333	250	200
	600	500	375	300
1:1:1	8–8–8	10–10–10	12–12–12	13–13–13
	200	160	133	123
	400	320	266	246
	600	480	400	370
2:1:1	14–7–7	16–8–8		
	200	175		
	400	350		
	600	525		
0:1:1	0–20–20	0–24–24	0–30–30	
	200	166	133	
	400	333	266	
	600	500	400	

Liquid Fertilizers

Liquid fertilizers available in Ohio include, in addition to the nitrogen solutions discussed in a previous section, many mixed fertilizers. Liquid fertilizers may supply a major part of the plant food needs of crops or may be used to supplement other fertilizers as in the use of starter solutions for tomatoes, and other horticultural or special crops.

Liquid fertilizers may be used in place of dry fertilizers. They are as good as, but no better than, dry fertilizers when equal quantities of available or soluble plant nutrients are supplied to the crop. Foliar application of liquid fertilizers on field crops are not recommended.

Manure

Animal Manures

The proper care and use of barnyard manures should be an important phase of the fertility program on all livestock farms. Barnyard manures contain plant nutrients, many of which are or become readily available. With proper handling, much of the nitrogen, phosphorus, potassium and the secondary and trace elements contained in farm crops can be returned to the soil in barnyard manure.

The average plant nutrient content of several animal manures is listed in Table 7.

The liquid portions of animal manures contain considerable quantities of plant nutrients. These nutrients are lost unless

TABLE 7
Average Composition of Animal Manures

Animal	Pounds Per Ton of Manure		
	Nitrogen (N)	Phosphoric Oxide (P_2O_5)	Potash (K_2O)
Cattle	10	3	7
Horses	13	5	9
Poultry	20	16	8
Sheep	21	6	18
Swine	10	7	13

ample bedding is used. In addition to the liquid absorbed by bedding materials, these materials themselves contain plant nutrients. The characteristics of several bedding materials are given in Table 8.

Portions of the nitrogen contained in animal manures may be lost to the air as ammonia vapor unless steps are taken to prevent this loss. The use of liberal quantities of bedding materials will keep this nitrogen loss to a minimum. Superphosphate fertilizers have the ability to combine with ammonia and to prevent its loss. Spreading superphosphate on the manure or in the barn gutter at the rate of 50 to 75 pounds of superphosphate per ton of manure will not only prevent the loss of ammonia but will raise the phosphorus content of the manure and make it a better balanced fertilizing material.

Green Manure Crops

Green manure crops are important in some grain crop rotations. One of the important benefits from the production of legume green manure crops is the nitrogen which these legumes fix in the soil. Table 9 lists typical nitrogen contents in pounds of nitrogen per acre in the tops and roots of alfalfa and sweetclover green manure crops obtained by studies at the Ohio Agricultural Experiment Station.

Recommended seeding mixtures and seeding methods for green manure crops are discussed in Ohio Extension Bulletin No. 380, "Meadow and Pasture Seedings."

TABLE 8
Characteristics of Several Bedding Materials

Material	Pounds of material required to absorb 100 pounds of liquid	Composition of Materials Pounds per ton: air dry		
		Nitrogen (N)	Phosphoric Oxide (P_2O_5)	Potash (K_2O)
Wheat straw	45	11	4	20
Oats straw	35	12	4	26
Chopped straw	20–30	..	..	..
Cornstalks (shredded)	25–35	15	8	18
Sawdust	25	4	2	4
Wood shavings	25–45	4	2	4

TABLE 9
Nitrogen Content of Legume Green Manure Crops Seeded in Oats

	Nitrogen—Pounds Per Acre					
	Alfalfa			Sweetclover		
	Tops	Roots	Total	Tops	Roots	Total
November of seeding year	39	35	74	34	95	129
Early May of year following seeding	83	25	108	78	37	115

Fundamentals of Fertilizer Application

Fertilizers supply, in an available form, the plant nutrients needed for crop growth which are not available in the soil. Where soil fertility levels are high, only small amounts of commercial fertilizers may be needed for maximum crop yields. However, where the fertility level of the soil is low, fertilizers must furnish a major portion of the nutrients needed by crops. In this case, large amounts of fertilizers must be applied, if maximum yields are to be attained.

The purpose of any fertilization program is to supply the plant nutrients which will result in the maximum or near maximum net return. Such a fertility program requires efficient use of fertilizers.

There is no one best fertilizer recommendation for all field crops and all soil conditions. All other factors remaining the same, the response of a crop to fertilizer will depend on the fertility level of the soil. Phosphorus fertilizer applied to a soil low in phosphorus will ordinarily produce a large yield increase; while the same amount of phosphorus applied to a similar soil which has a high level of phosphorus may produce little or no yield increase.

Maintaining soil fertility at medium or higher levels is a desirable long-term soil fertility program. It sets the stage for high yields and use of labor-saving practices in fertilizer usage. Continued high crop yields are most certain when soils contain abundant, well-balanced supplies of phosphate and potash along with other elements.

Fertilizer Systems (Row Application and Building Reserves)

Results of research conducted at the Ohio Agricultural Experiment Station provide data for studying the effects of two fertilizer systems. In this research, three levels of soil phosphorus, low, medium and high, were established by bulk applications of varying amounts of phosphorus fertilizers. Nitrogen and potassium were supplied in liberal quantities. Corn planted on each of these plots received three rates of phosphorus fertilizer—0, 10, and 30 pounds of P_2O_5 per acre. Corn yield data are shown in Table 10.

TABLE 10

Yield of Corn as Affected by Rate of Row Phosphorus and Soil Phosphorus Level

(O.A.E.S. Wooster)

	Soil Phosphorus Level		
Pounds row P_2O_5/A/Yr	Low Bu/A	Medium Bu/A	High Bu/A
	1953–1958 Average		
0	86	89	94
10	91	96	95
30	98	98	97

At the low level of soil phosphorus, an application of 30 pounds of P_2O_5 increased corn yields by 12 bushels while on the plots with high soil phosphorus the 30-pound application of P_2O_5 gave only a 3-bushel yield increase.

A similar experiment was conducted with potassium, and here, too, a large yield increase was obtained from applications of potassium to corn grown on soils low in potassium while lesser increases resulted from potassium fertilization of corn grown on high potash soils.

Small grains and meadow crops grown on plots with varying soil fertility levels showed the same general trend.

Deficiencies of phosphorus and or potassium may be corrected and brought into proper balance by either of two plans:

1) For a gradual build-up, apply each year more of the deficient element than is

removed by the growing crop (see Table 1). Once a high level has been reached, use a maintenance application.

2) For a more rapid build-up, make large applications of the deficient element once or twice during each rotation and then follow with maintenance fertilization for each crop.

These two fertilization plans are illustrated in Table 11. In this illustration, it is assumed that the soil is low in phosphorus and potassium and that a four-year rotation of corn, wheat, meadow, meadow is to be followed. It will be noted that even though the route taken in each case is different, they both arrive at practically the same point, i.e., 322-324 pounds of P_2O_5 and K_2O applied.

Nitrogren may be lost by leaching; therefore, nitrogen fertilizers should be applied on an annual basis. Nitrogen can be stored in the soil for long periods of time only when it is combined in organic matter. Organic matter releases nitrogen as it decomposes. Nitrogen from commercial fertilizers has its greatest effect within the growing season of its application.

Fertilizer Placement

Fertilizers are applied by several methods; broadcasting either prior to plowing or on plowed ground prior to planting of the crop, applications at the time of planting the crop, topdressing, sidedressing, applications in irrigation water, and foliar spraying.

In choosing the method to use for an individual situation consideration should be given to several factors including the fertility level of the soil, the crop to be grown and the equipment available.

Fertilizers should be applied in such a manner that:

1) Growing plants can use the fertilizer efficiently.

2) There is little or no injury to plants from the fertilizer.

3) The job can be accomplished as quickly and as easily as is economically possible.

TABLE 11
Alternative Soil Fertility Plans

Crop	Fertilizer lb.	Fertilizer grade	Pounds P_2O_5	Pounds K_2O
		Plan 1		
Corn	200	4–16–16 row	82	82
	250	0–20–20 plow down		
Wheat	500	4–16–16	80	80
Meadow	400	0–20–20	80	80
Meadow	400	0–20–20	80	80
	Total for rotation		322	322
		Plan 2		
Build-up application	1000	0–20–20	200	200
Corn	200	4–16–16	32	32
Wheat	200	4–16–16	32	32
Meadow (1st or 2nd year)	300	0–20–20	60	60
	Total for rotation		324	324

Broadcast

Broadcast applications of phosphorus and/or potash are made when large amounts are needed to correct serious soil deficiencies or to bring the fertility status of soils into proper balance. Phosphorus is held in the soil with little loss except by removal in harvested crops or by erosion of the soil. Potash also can be stored in most soils without serious loss from leaching; however, it may be lost by leaching from sandy or strongly acid soils. When potash levels are high, legume crops take up more potash than is needed for maximum growth; most of this potash is recovered in manure when the legumes are fed to livestock on the farm.

Nitrogen fertilizers may be broadcast and plowed down for crops such as corn, sugar beets, and tobacco. For recommendations regarding nitrogen plow down, see pages 27 and 28.

Fertilizers containing N, P, and K are plowed down when large amounts of all three elements are needed. When this is done, the usual precautions must be taken to prevent the loss of nitrogen by leaching.

Row Placement

Most fertilizers used in Ohio are applied *with the seed at planting time.* This "starter" or "band placed" fertilizer is important because it stimulates rapid seedling growth and gets crops off to a good start. Amounts of fertilizer which can safely be used and methods of placement vary with crops.

Corn—Row fertilizer for corn should be placed in a band 2 inches to the side and 2 inches below the seed. With this placement a total of 80 pounds per acre of nitrogen and/or potash can safely be applied at planting time (300 lbs. of a 5-20-20 fertilizer contains 15 lbs. of nitrogen and 60

Courtesy American Potash Institute

Topdressing meadow with fertilizer.

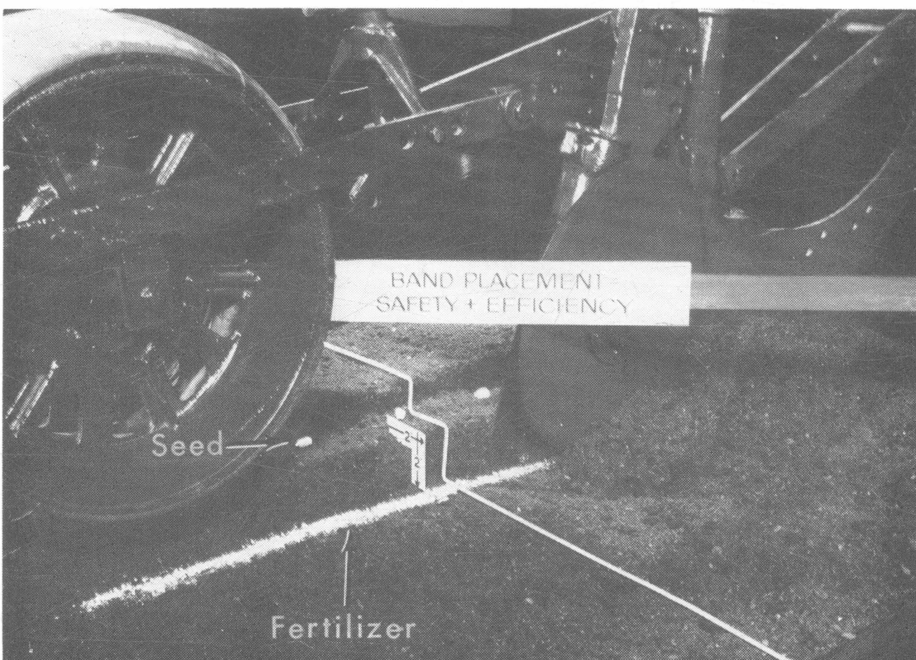
lbs. of potash or a total of 75 lbs. of salts).

Soybeans—Row fertilizers for soybeans should be placed as recommended for corn —2 inches to the side and 2 inches below the seed. However, because soybeans are particularly susceptible to fertilizer injury the total "salts" (nitrogen plus potash) should not exceed 30 pounds per acre. Where larger amounts of potassium are needed at least a part of the fertilizer should be broadcast prior to planting.

Small Grains — Recent research from other states has shown that small grains may at times be injured by applications of large amounts of fertilizer at planting time when this fertilizer comes into direct contact with the seed. Ohio research has shown no ill effects from 500-700 pounds per acre of standard grade complete fertilizers applied in this manner.

Meadows and Pastures—Band seeding is recommended for seeding with oats and those made without a companion grain crop. In order to band seed, arrange the hose or tubes from the seed box so that the legume seeds fall 10 to 12 inches behind the disks and directly over the band of fertilizer. Nothing is gained if the legume seed falls one-half inch or more to one side of the fertilizer band.

See Extension Bulletin 380 or Leaflet L-79 for detailed instructions regarding band seeding of forage crops.



Courtesy American Potash Institute

Side band placement of fertilizer.

Topdressing

Meadows and pastures may be topdressed with phosphorus and/or potassium at any time during the year with the exception that fertilizers applied to frozen ground may be carried from the field if a heavy rain should occur while the ground is frozen. Many farmers prefer to topdress meadows immediately following the first cutting. Although this is a satisfactory time of application, it is no better than several others.

Winter grains may be topdressed with nitrogen or with complete fertilizers where phosphorus and/or potassium are needed in addition to nitrogen. These topdressing applications should be made during the late winter or very early spring months.

Sidedressing

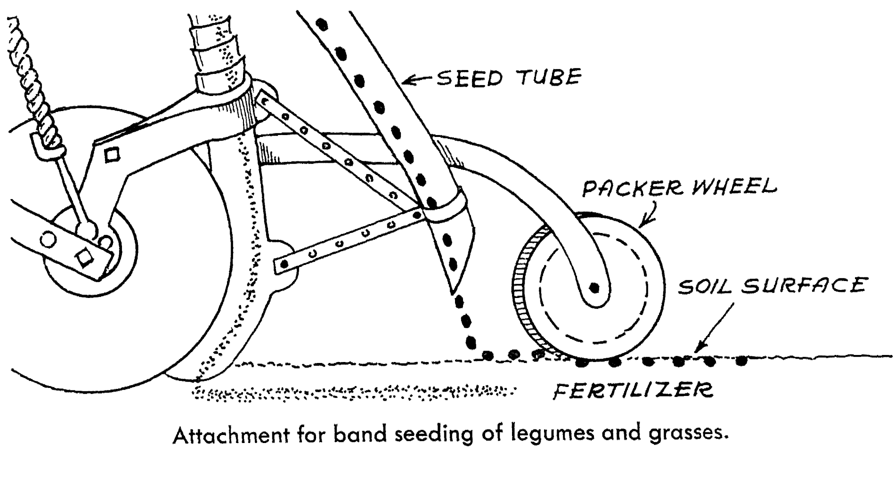
In Ohio sidedressing is used almost exclusively as a means of applying additional nitrogen to corn. In general, plow down or row applications of nitrogen are preferable to sidedressing. Where corn is to be sidedressed with nitrogen, the fertilizer should be applied in bands 3 to 4 inches below the soil surface between the corn rows. This application should be made when the corn is 6 to 12 inches tall. Deep sidedressing close to the corn plants will damage corn roots and may reduce yields.

Irrigation

Irrigation water as a means of fertilizer application is used only to a very limited extent in Ohio. Where irrigation is practiced, water soluble fertilizers can frequently be applied easily and economically with the irrigation water.

Foliar Spraying

This method is not recommended as a means of applying complete fertilizer on field crops, because sufficient nutrients cannot be safely applied for best crop growth.



Attachment for band seeding of legumes and grasses.

Courtesy American Potash Institute

Broadcasting fertilizer on pasture.

Residual Effects of Fertilizer

The residual effect, or carryover, of fertilizer varies greatly. Carryover is affected by the type of fertilizer, rate of fertilizer application, soil texture, rainfall, the crop grown, and the crop yield.

Although nitrogen should be applied on an annual basis, there frequently is some carryover from large applications of nitrogen. This is particularly true on fine-textured soils following years of low rainfall.

Where large amounts of phosphorus and/or potassium are applied, the effect may be expected to last for several years. This is the basis for the recommendation of a build-up application of these elements (see pages 21 and 22).

General Consideration in Fertilizing Major Field Crops

Corn

High corn yields can be obtained only when soil and climatic conditions are such that plants make continuous, vigorous growth. When climatic conditions are near average, corn yields are greatly influenced by soil fertility levels and corn production practices.

Corn fertilization may be broken down into three considerations:

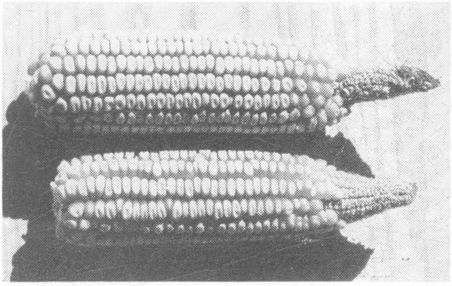
1) Starter or row fertilization.

2) Broadcast applications of supplemental phosphorus and/or potassium for the corn and succeeding crops.

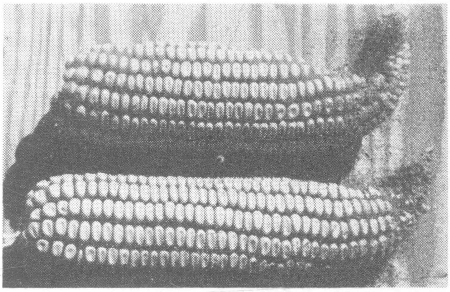
3) Supplemental nitrogen.

Many experiments have shown row fertilization to be of considerable benefit in increasing corn yields. These yield increases may be due to an increased total supply of readily available nutrients, better stands, or increased seedling vigor. As the soil fertility level is raised, there is less yield response to starter fertilizers. However, since it is not possible to predict the yield increase which may result from row fertilization of corn on high fertility soils it is good management and insurance to use starter fertilizer on all fields at planting time.

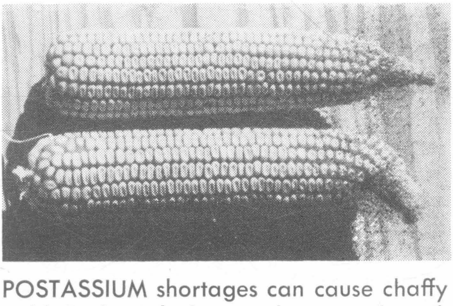
Fertilizer ratios suggested for corn at planting time may range from 1-4-2 to 1-4-4 to 1-2-2 to 1-4-0. The ratio of fertilizer best suited for a specific situation will largely depend on the relative level of soil phosphorus and potassium, as determined by soil tests. For example, where soils are low in phosphorus and high in potassium the starter fertilizer should be one relatively higher in phosphate as compared to potash, such as the 1-4-2 or 1-4-0 ratios.



NITROGEN shortages result in ears with unfilled tips sharply pinches off. Normal luster.



PHOSPHORUS deficiencies often are responsible for crooked and missing rows of kerns in twisted and small ears.



POSTASSIUM shortages can cause chaffy nubbins, kernels that are loose on the cob and dull in color, and unfilled tips.

Courtesy American Potash Institute

In some situations, it is desirable to apply larger amounts of phosphorus and/or potassium than can safely or conveniently be applied at planting time. This extra fertilizer may be broadcast and plowed down.

This will place the extra fertilizer deeper in the soil where moisture is more plentiful. Plow down applications of phosphorus and potassium are not used as efficiently by the immediate corn crop as are starter fertilizers. Plow down applications do, however, serve to build up a fertility reserve which can be used by the corn and succeeding crops. Where corn follows a good legume sod, a vigorous legume green manure crop, or where large amounts of barnyard manure are applied, it normally responds profitably to applications of supplemental nitrogen. Supplemental nitrogen frequently increases corn yields where corn follows an average or fair legume sod. Past experiences and sound judgment aid in determining the amount of supplemental nitrogen which will return the maximum profit.

If a good legume sod is plowed down, perhaps no supplemental nitrogen will be needed. Following poor to fair legume sods, an application of 40 to 60 pounds per acre of nitrogen should be used. When corn does not follow a legume sod, 80 to 120 pounds per acre of supplemental nitrogen will usually be more profitable than a lower rate.

Small Grains

With Forage Seedings

One of the major problems in fertilizing small grains which serve as companion crops for forage seedings is to get a balance between nitrogen and phosphorus—potassium applications which will give high grain yields and at the same time permit the establishment of good meadow and pasture seedings. Of the primary nutrients, nitrogen has the greatest effect on small grain yields. However, too much nitrogen may cause the grain crop to lodge or to make such a rank growth that the forage seeding is damaged.

Phosphorus and potassium are especially important in the establishment and growth of legumes and grasses. Fertilizer ratios approximating 1-4-2 or 1-4-4 are especially adapted for use on small grain crops which are seeded to grasses and legumes.

Without Forage Seedings

High nitrogen fertilizers are usually in order when a forage seeding is not made in the small grain. In many instances, 1-1-1 ratio fertilizers best fit these situations.

Supplemental Nitrogen for Winter Grains

When wheat comes through the winter in poor condition it frequently gives a profitable response to spring topdressing with nitrogen. Where adequate phosphorus and potassium were applied at planting time, nitrogen at a rate of 30 pounds per acre is suggested for this spring topdressing. Where additional phosphorus and potassium are needed, a 1-1-1 ratio fertilizer should be used as the spring topdressing.

Soybeans

Soybeans respond less to direct fertilization than do corn, small grains, or forage crops. They do, however, produce larger yields under high levels of soil fertility brought about by fertilizing other crops in the rotation. Where the phosphorus and/or potassium levels in the soil are low, soybeans should be fertilized with 150 to 200 pounds per acre of grades such as 0-20-20 or 0-20-10 or 0-20-0. See page 24 for recommendations regarding fertilizer placement.

Meadows and Pastures on Rotation Cropland

Fertilization at Time of Seeding

On all except the very high nitrogen soils, forage grasses respond to small amounts of nitrogen at planting time. On low-nitrogen soils, legumes also respond to nitrogen at planting time. Phosphorus stimulates seedling growth and it is especially important that young forage plants be supplied with plenty of readily available phosphorus. Ohio soils usually contain enough potassium for forage seedling establishment; however, high producing forages remove large quantities of potassium and part of this needed potassium can be applied at planting time.

On low fertility soils, the started fertilizer for forage seedings should approximate a 1-4-2 or 1-4-4 ratio. On high fertility soils 0-1-1, 0-2-1 or 0-1-2 ratios may be desired. See Extension Bulletin 380 or Leaflet L-79 for recommended seeding mixtures and seeding methods.

Spring seedings in wheat, winter barley or rye on soils very low in phosphorus are often benefited by applications of phosphorus fertilizers with the seeding. The recommended application is 200 pounds of 0-20-0 or 125 pounds of 0-20-20 or 0-20-10 per acre drilled with the legume seed.

Topdressing

Meadows and pastures may be topdressed during the fall, early spring or following any harvest.

The fertilizer ratio to be used should be selected on the basis of needs as indicated by soil tests. One of the following ratios, 0-1-1, 0-2-1, 0-1-3, 0-1-0, or 0-0-1, will fit the various combinations of soil fertility levels. Legumes fix nitrogen from the air, thus where the stand consists of 50 percent or more legumes, the topdressing fertilizer need not contain nitrogen.

Fertilizing Permanent Pastures (Blugrass)

On unimproved permanent pastures in Ohio, the application of phosphate is very important in beginning a fertility program to rejuvenate such pastures. The basic treatment should approximate 100 to 120 pounds of phosphate (P_2O_5) per acre. For example, 500 pounds 0-20-0 fertilizer would supply 100 pounds of P_2O_5. This may be applied any time during the growing season.

Once the basic fertility treatment has been completed, fertilizer ratios including both phosphate and potash, such as 0-2-1 or 0-1-1, should be used to maintain the pasture.

After the pasture is rejuvenated, nitrogen becomes of primary importance in the production of bluegrass, or any other grass, in contrast with legumes which have relatively greater need for phosphate and potash.

An application of 40 to 60 pounds per acre of nitrogen on fair to good sods will advance early spring grazing by two weeks and will greatly increase spring growth. This application may be made in the fall or early spring. The acreage treated should not exceed one-third acre for each cow or animal unit to be grazed. Where all fertilizer nutrients are needed, the use of 1-1-1 or 2-1-1 ratios is suggested.

Miscellaneous Crops

Sugar Beets

Sugar beets respond to liberal amounts of readily available plant food. The soil pH should be at least 6.5 for maximum yield. This crop is particularly sensitive to soil physical properties. Hence, the soil should be in a good state of tilth with greater than average water-holding capacity.

For best results the fertilizer should be placed in a band 1.5 to 2 inches to the side of the row and 1 to 2 inches below the seed. With such placement 400 to 600 pounds of fertilizer may be safely applied at the time of seeding sugar beets. Where the fertilizer is placed in direct contact with the sugar beet seed, not more than 20 pounds of nitrogen and or potash should be used. In other words, 100 to 150 pounds of a 1:4:2 or 1:4:4 ratio of fertilizer would be the limit in this instance.

Supplemental nitrogen fertilization is recommended especially when the sugar beet crop does not follow a good alfalfa or sweet clover legume in the crop rotation. Sixty to 120 pounds of nitrogen per acre may be plowed down or sidedressed. It is advisable to sidedress early, soon after blocking. Applications late in the season are not suggested because a reduced percentage of sucrose may result.

Fertilizing Burley Tobacco

Tobacco grown on deep well-drained soils responds well to liberal amounts of commercial fertilizer. Rates of 1,000 to 2,000 pounds of 5-10-15 per acre plus 20 to 40 pounds of additional nitrogen should be used. The potash in tobacco fertilizers should be predominantly in the sulfate form.

Up to 600 pounds of 5-10-15 per acre may safely be banded in the row. However, where more than this amount of fertilizer per acre is used it is recommended that the entire amount be plowed down or disked in. On well fertilized soils it is generally not necessary to make row applications or to add starter solutions to tobacco at setting time.

The application of 8 to 10 tons of well-rotted manure is advisable, especially on soils low in organic matter or in continuous tobacco culture. Where manure is applied, rates of commercial fertilizer may be reduced accordingly.

Tobacco needs about 120 pounds of nitrogen per acre for good growth. Part of this can be supplied by plowing down manure or a legume sod or cover crop. Generally 60 to 120 pounds of commercial nitrogen should be used depending upon the quality of the manure or legume sod. There are many hazards involved with over-fertilization of burley tobacco with nitrogen.

Broadcast applications of nitrogen may be plowed down or disked in after plowing. If the application is plowed down, it should be done just before plowing to reduce leaching. Late sidedress applications should be avoided because of the tendency to lower tobacco quality.

SOIL TESTS PAY

A sound fertilization program is one designed to meet the needs of all of the crops in the rotation. This kind of a soil treatment program should be based on the results of a complete, accurate soil test.

Soil tests furnish a basis for soil building and crop fertilization. They allow you to spend your fertilizer dollars more wisely. For specific recommendations get a soil test every 3 to 5 years.

Soil tests are available through your County Agricultural Extension office. Ask your county agent for directions for taking representative samples of your soil.

These soil samples, submitted by your county agent, are processed by the Ohio Agricultural Extension Service Soil Testing Laboratories.

Send your samples early. Just before planting time the laboratory is very busy, so late samples may mean delayed reports.

Don't Guess . . . Soil Test!!